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Rare decays in B physics at CMS

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Summary. — Results on the angular analysis and differential branching fraction measurement of the decay $B^0 \to K^{*0}\mu^+\mu^-$ are presented. The measurement of the forward-backward asymmetry of the muons, the K^{*0} longitudinal polarization fraction, and the differential branching fraction, as a function of the square of the dimuon system invariant mass, is reported. The results are in very good agreement with the Standard Model expectations. This analysis is performed using a data sample corresponding to an integrated luminosity of $5.2\,\mathrm{fb}^{-1}$ collected with the CMS detector at the LHC in proton-proton collisions at $\sqrt{s} = 7\,\mathrm{TeV}$.

1. – Introduction

Rare decays are those processes that are highly suppressed according to the Standard Model (SM) predictions. These decays are an excellent laboratory to probe SM, since an eventual new physics contribution would have an amplitude comparable with the expected one and it would considerably modify the features of the process. The CMS Collaboration gave its significant contribution to the study of two rare decays within the heavy-flavour physics: the $B^0_{d(s)} \to \mu\mu$ decays [1] and the $B^0 \to K^*(892)^0\mu\mu$ decay [2]. Here only the latter decay analysis is reported.

The flavour changing neutral current decay $B^0 \to K^*(892)^0\mu^+\mu^-$ is particularly fertile for new phenomena searches thanks to the modest theoretical uncertainties, due to the semileptonic final state. Furthermore, this decay is forbidden at tree level and the leading order diagrams that mediate this process are the box and penguin ones. This fact makes this decay channel very sensitive to virtual contributions of new particles.

In this three body decay, there are two angular parameters that have small theoretical uncertainties: the forward-backward asymmetry of the muons, A_{FB}, and the K^{*0} longitudinal polarization fraction, F_L. These parameters, along with the differential branching fraction $\mathrm{d}B/\mathrm{d}q^2$, can be determined as a function of the dimuon invariant mass squared, q^2, and compared with the SM expectations.

2. – Analysis

The CMS collaboration performed this analysis [2] using data collected from proton-proton collisions at the Large Hadron Collider (LHC) with the Compact Muon Solenoid (CMS) experiment in 2011 at a center-of-mass energy of 7 TeV. The analyzed dataset corresponds to an integrated luminosity of $5.2 \pm 0.1\,\mathrm{fb}^{-1}$.

2˙1. *Angular parametrization.* – The considered final state contains two opposite charged muons and a kaon and a pion as the decay products of the K^{*0}. Three angular variables are defined to describe completely the decay: the angle between the kaon momentum and the direction opposite to the B^0 in the K^{*0} rest frame, θ_K, the angle between the positive (negative) muon momentum and the direction opposite to the B^0 ($\bar{B}^0$) in the dimuon rest frame, θ_l, and the angle between the plane containing the two muons and the plane containing the kaon and the pion, ϕ.

Contribution from spinless $K\pi$ combination is present, although the $K\pi$ invariant mass is imposed to be consistent with the K^{*0} one. The fraction of S-wave contribution is parametrized as F_S and the interference contribution between S-wave and P-wave is A_S.

The angular distribution of the decay is then

$$\begin{aligned}\frac{1}{\Gamma}\frac{\mathrm{d}^3\Gamma}{\mathrm{d}\cos\theta_K \mathrm{d}\cos\theta_l \mathrm{d}q^2} = \frac{9}{16}\Bigg\{ & \left[\frac{2}{3}F_S + \frac{4}{3}A_S\cos\theta_K\right](1-\cos^2\theta_l) \\ & + (1-F_S)\Bigg[2F_L\cos^2\theta_K(1-\cos^2\theta_l) \\ & + \frac{1}{2}(1-F_L)(1-\cos^2\theta_K)(1+\cos^2\theta_l) \\ & + \frac{4}{3}A_{FB}(1-\cos^2\theta_K)\cos\theta_l\Bigg]\Bigg\},\end{aligned}$$

where the dependence on ϕ is integrated out, since the A_{FB} and F_L parameters do not depend on it.

2˙2. *Control samples and background events.* – The range of q^2 considered goes from $1\,\mathrm{GeV}^2$ to $19\,\mathrm{GeV}^2$ and it is divided in eight bins of different width. The fourth and the sixth bins correspond to the mass resonances of J/ψ and ψ'. The former one contains mass square values in the range $8.68\,\mathrm{GeV}^2 < q^2 < 10.09\,\mathrm{GeV}^2$ and the events here contained are used as normalization sample, to normalize the branching fraction measurement. The latter resonance bin covers a range with $12.86\,\mathrm{GeV}^2 < q^2 < 14.18\,\mathrm{GeV}^2$ and its events are used as control sample.

After the selection cuts and the K^{*0} mass requirement, the background contamination is composed of combinatorial one and the peaking one. The latter is originated by J/ψ and ψ' events that elude the two resonance bins.

2˙3. *Fit algorithm and results.* – In order to extract the values of the angular parameters and the signal and background yield, a simultaneous unbinned maximum likelihood fit to the B^0 recontructed mass, to $\cos\theta_K$ and to $\cos\theta_l$ is performed for each q^2 bin.

The fit results are plotted in fig. 1. In the fifth q^2 bin no SM prediction is plotted since no reliable models are available. The results are in good agreement with the expectations.

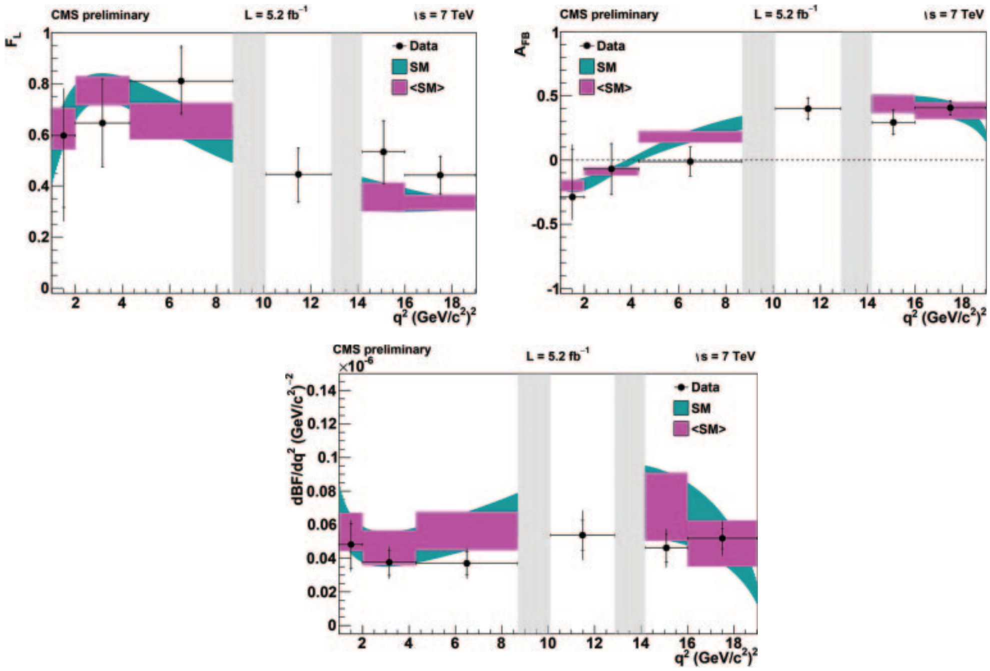

Fig. 1. – Results of the measurement of F_L (top left), A_{FB} (top right) and $\mathrm{d}B/\mathrm{d}q^2$ (bottom) *vs.* q^2. The statistical uncertainty is shown by inner error bars, while the outer error bars give the total uncertainty. The vertical shaded regions correspond to the J/ψ and ψ' resonances. The other shaded regions show the SM prediction as a continuous distribution and after rate-averaging across the q^2 bins (SM) to allow direct comparison to the data points. Reliable theoretical predictions between the J/ψ and ψ' resonances ($10.09 < q^2 < 12.86\,\mathrm{GeV}^2$) are not available. Figure from [3].

3. – Conclusions

The angular analysis of the $B^0 \to K^{*0}\mu^+\mu^-$ decay has been presented. The measured values of A_{FB}, F_L and of the differential branching fraction $\mathrm{d}B/\mathrm{d}q^2$ are compatible with the SM predictions. Since the experimental uncertainty is dominated by the statistical error, a great precision improvement is expected repeating this analysis with more statistics. A recent LHCb mesurement [4] shows a discrepancy whith the expectations and this raises great interest in this analysis.

REFERENCES

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